at 8.30 it reached the zenith. In this position—from the northern horizon to zenith—the phenomenon remained almost uninterrupted all the following time. The light was rather feeble, and in the beginning the motions were insignificant. But at 10 o'clock the peculiar blazing or undulating movement that is designated by the name of *coruscation*, began to be seen, and during four hours and a half at least the whole northern half of the sky was the theatre of this uncommonly violent chase of the luminous clouds. The culmination of the aurora happened at 10.30, when on the northern sky advanced a series of splendid streamers, the inferior points of which played in red and green. This radiance was only of short duration, and later there appeared in the north only arches more or less distinct; while on the higher parts of the heavens the chasing flames incessantly continued their playing. Still, so late as 14.30 saw the flames as far as to the zenith with unimpaired violence.

I may add that on this occasion I succeeded in what I myself, as well as other friends of the aurora, have tried before in vain, viz. *to get the aurora to make impression on a photographic plate.* I exposed in all five plates; of these four (for times of exposure of 2-4 minutes) without the least trace of action, but the fifth, which was exposed during 8½ minutes, shows both a part of the horizon with a high church spire and a feeble representation of a portion of the aurora. I must, however, state that this portion in itself was but very feebly illuminated, and that at the time when the phenomenon developed the greatest power of light I was prevented from applying the camera.

The object-glass employed was: Voigtländer euroscope, No. 1; Schleussner's dry plates.

Also on the 16th, in the evening, 8.45 to 10, there appeared an aurora, but consisting essentially only of feeble fragments of arches rather low on the northern sky. The aurora has in recent times been astonishingly rare: here in Christiania, in the course of the whole winter, it has been observed on the following days:—September 14, 17, 24; October 14, 15; November 17; December 22; January 22; February 14, 16; March 12, 15, 16.

March 15 excepted, all these auroræ have been rather insignificant. SOPHUS TROMHOLT

Christiania, March 17

"Peculiar Ice Forms"

UNDER the above caption, several correspondents of NATURE have recently described and discussed the agglutinated filamentoid ice-crystals commonly extruded from unfrozen earth under suitable conditions of moisture and temperature. B Woodd Smith records their occurrence in the Savoyan Alps (his language implying variety of the phenomena there), and attributes them to the linear expansion incident to congelation of capillary columns of water in a thin sheet of soil resting upon rock (vol. xxxi. pp. 5-6). W. alludes to such crystals in general terms, refers to a previous notice of similar phenomena, and (erroneously) allies them genetically to hoar-frost (*ib.*, p. 29). Dr. John Rae discusses distinct (but erroneously supposed similar) phenomena at length, and argues that the several strata of crystals are remnants of successive sheets of ice or snow (*ib.*, pp. 81-2). Mr. Smith then controverts Mr. Rae's explanation, maintains his own, and refers to several earlier communications in NATURE relating to filamentoid ice-crystals (*ib.*, pp. 193-4); and sebsequently he transmits a letter from John D. Paul, who has essentially repeated his own observations in the Alps (*ib.*, p. 264).

Now that it has become fashionable to revive forgotten records, it may be pointed out that these correspondents ignore the more valuable portion of the literature of their subject. Even in NATURE discussion of the fibrous ice-crystals extruded from moist earth, wet wood, &c., was epidemic fifteen years ago, and again ten years later, besides the sporadic cases of three years ago, as shown in the following bibliography:—

1870	Vol. I.	—C. Spence Bate	p. 556
,,	,,	—Mr. Pengelly	p. 627
,,	Vol. II.	—T. G. Bonney, John Langters (*sic*)	pp. 141-2
1871	Vol. III.	—T. G. Bonney, John Langton	pp. 105-7
,,	,,	—T. G. Bonney	p. 288
1880	Vol. XXI.	—Argyll	p. 274
,,	,,	—R. Meldola	p. 302
,,	,,	—Argyll	p. 368
,,	,,	—O. Fisher	p. 396
1880	Vol. XXI.	—D. Wetterhan	p. 396
,,	,,	—L. Bleekrode	p. 444
,,	,,	—S. T. Barrett	p. 537
,,	,,	—Wm. Le Roy Broun	p. 589
,,	Vol. XXII.	—John Le Conte	p. 54
,,	,,	—R. H.	pp. 145-6
1882	Vol. XXV.	—J. F. Duthie	p. 78
,,	Vol. XXVI.	—H. Warth	p. 81

The second outbreak was practically terminated by the communications of Profs. Broun and Le Conte. The first of these gentlemen wrote from a locality in which the phenomena are readily observable, while the latter called attention to his own elaborate researches of thirty years before (*Proc. Am. Assn. Adv. Sci.*, iii. 1850, p. 20-34; *Phil. Mag.*, third series, xxxvi. 1850, pp. 329-42).

More recently (February 6, 1884) Prof. Schwalbe has placed before the Physical Society of Berlin the results of his observations upon filamentoid ice-crystals in the Harz. After thorough study he accepts Le Conte's views as to their genesis.

Prof. Le Conte's explanation (which is essentially identical with that subsequently offered independently by Prof. Broun) is as follows:—"Let us suppose a portion of tolerably compact porous and warm earth saturated with moisture, to be exposed to the influence of a cold-producing cause. The soil being an imperfect conductor of heat, only a very superficial stratum would be reduced to the freezing point. As the resistance to lateral expansion is less at the surface than it is at] a sensible depth below, the effect of the first freezing would be to render the apices of the capillary tubes or pores conical or pyramidal. The sudden congelation of the water, filling the conical capillaries in the superior stratum, would produce a rapid and forcible expansion, which, being resisted by the unyielding walls of the cone, would not only protrude, but *project* or *detach and throw out* the thread-like columns of ice, in the direction of *least resistance*, or perpendicular to the surface. This would leave the summits of the tubes *partially empty*—a condition essential to the development of capillary force. Under these circumstances capillary attraction would draw up warm water from beneath, which, undergoing congelation, would, in like manner, elevate the column of ice still higher; and thus the process would go on as long as the cold continued to operate on unobstructed capillaries, supplied with sufficient water from below. It will be remarked that this explanation makes the whole process of protrusion to take place in a stratum of earth of almost inappreciable thickness. It also presumes that the protruding force act[s] *paroxysmally*" (*Proc. Am. Assn. Adv. Sci.*, *op. cit.*, 30-31). He subsequently remarks (NATURE, *op. cit.*): ". . . In relation to the explanation of the phenomena, I have nothing to add to that given" above, "except in relation to *two points*, viz.: (1) that I did not sufficiently *emphasise* the importance of the fact that the water contained in the *capillary* tubes in the upper stratum of earth is cooled many degrees below the freezing temperature; and (2) that consequently the congelation would necessarily take place *paroxysmally.*"

It may be pointed out also that the great majority of the correspondents, both recent and earlier, base their explanations upon isolated observations of phenomena rare in their localities. In reality the extrusion of filamentoid ice-crystals is even more common in certain localities than is indicated by Le Conte's papers and Broun's letter. Thus, in the cultivated fields of the Mississippi valley, during a cloudy day following an autumnal rain, with an air temperature just below freezing-point, the writer has seen a thin layer of soil elevated from one to three inches over fully four-fifths of the area visible from the road throughout a day's journey. Greater length is sometimes attained by the crystals. Within a week the writer has observed, along the roadsides just beyond the limits of Washington, many irregular patches and belts of straight or slightly curved filamentoid crystals, four, six, and even eight inches in height. They were sometimes highest where they supported the greatest weight of earth, leaves, twigs, or pebbles upon their summits. In one case a worn quartzite pebble 1 × 1½ × 2⅛ inches was hoisted on a slender tuft of icy needles six or seven inches long, fully two inches above the smaller neighbouring pebbles and the film of soil in which it had been imbedded.

While Le Conte's theory of the formation of the filamentoid crystals extruded from moist earth or wet vegetal stems is acceptable in a general way, repeated observation upon crystals apparently in process of development has convinced the writer that their growth is not paroxysmal. The effect of capillarity

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in the moist substance is to keep the bases of the icy filaments, or the lower side of the stratum formed by their agglutination, wet; and congelation of this film appears to be continuous.

W. J. McGee

U.S. Geological Survey, Washington, D.C., U.S.A., February 1

Four-Dimensional Space

Possibly the question, What is the fourth dimension? may admit of an indefinite number of answers. I prefer, therefore, in proposing to consider Time as a fourth dimension of our existence, to speak of it as *a* fourth dimension rather than *the* fourth dimension. Since this fourth dimension cannot be introduced into space, as commonly understood, we require a new kind of space for its existence, which we may call time-space. There is then no difficulty in conceiving the analogues in this new kind of space, of the things in ordinary space which are known as lines, areas, and solids. A straight line, by moving in any direction not in its own length, generates an area; if this area moves in any direction not in its own plane it generates a solid; but if this solid moves in any direction, it still generates a solid, and nothing more. The reason of this is that we have not supposed it to move in the fourth dimension. If the straight line moves in its own direction, it describes only a straight line; if the area moves in its own plane, it describes only an area; in each case, motion in the dimensions in which the thing exists, gives us only a thing of the same dimensions; and, in order to get a thing of higher dimensions, we must have motion in a new dimension. But, as the idea of motion is only applicable in space of three dimensions, we must replace it by another which is applicable in our fourth dimension of time. Such an idea is that of successive existence. We must, therefore, conceive that there is a new three-dimensional space for each successive instant of time; and, by picturing to ourselves the aggregate formed by the successive positions in time-space of a given solid during a given time, we shall get the idea of a four-dimensional solid, which may be called a sur-solid. It will assist us to get a clearer idea, if we consider a solid which is in a constant state of change, both of magnitude and position; and an example of a solid which satisfies this condition sufficiently well, is afforded by the body of each of us. Let any man picture to himself the aggregate of his own bodily forms from birth to the present time, and he will have a clear idea of a sur-solid in time-space.

Let us now consider the sur-solid formed by the movement, or rather, the successive existence, of a cube in time-space. We are to conceive of the cube, and the whole of the three-dimensional space in which it is situated, as floating away in time-space for a given time; the cube will then have an initial and a final position, and these will be the end boundaries of the sur-solid. It will therefore have sixteen points, namely, the eight points belonging to the initial cube, and the eight belonging to the final cube. The successive positions (in time-space) of each of the eight points of the cube, will form what may be called a time-line; and adding to these the twenty-four edges of the initial and final cubes, we see that the sur-solid has thirty-two lines. The successive positions (in time-space) of each of the twelve edges of the cube, will form what may be called a time area; and, adding these to the twelve faces of the initial and final cubes, we see that the sur-solid has twenty-four areas. Lastly, the successive positions (in time-space) of each of the six faces of the cube, will form what may be called a time-solid; and, adding these to the initial and final cubes, we see that the sur-solid is bounded by eight solids. These results agree with the statements in your article. But it is not permissible to speak of the sur-solid as resting in "space," we must rather say that the section of it by any time is a cube resting (or moving) in "space."

S.

March 16

The Action of Very Minute Particles on Light

The action upon transmitted light of very minute particles suspended in a transparent medium is very well known, thanks to the investigations of Brücke, Tyndall, and others, up to a certain point. That is to say, that white light, passing through varying depths of a medium with such particles more or less thickly interspersed, is known to emerge coloured yellow, orange, or red, according to the extent of the action in question. Wishing to illustrate this phenomenon experimentally, I employed a very dilute solution of sodium thiosulphate (hyposulphite), which was acidified with hydrochloric or sulphuric acid, and then allowed to stand, observing from time to time the appearances when examined by transmitted light. The solution mentioned is admirably adapted for the purpose, inasmuch as the precipitation of the sulphur proceeds gradually; and, according to the greater or less dilution at starting, the completion of the reaction can be spread over a long period of time, in some of my experiments occupying more than forty-eight hours. For a while no turbidity whatever is visible; then a faint opalescence makes its appearance, and these exceedingly minute particles grow gradually in size, remaining, however, quite uniformly suspended for a considerable period, until a dimension is reached which causes them to settle out of the liquid. In this way I observed with unfailing regularity, and in unvarying order, though with various degrees of rapidity, an extension of the series of colours, which, so far as I am aware, had not previously been noticed, or at any rate published. From orange, the tint passed successively through rose red, purplish rose, to a full purple; then by insensible gradations to a fine violet, blue, green, greenish yellow, neutral tint, &c.

The solution was contained in spherical or pear-shaped flasks, or in cells with flat and parallel sides. A solution which was strong enough to give well-marked yellow, orange, and red tints, was not well adapted for the subsequent stages, as it soon became white and opaque, so that the later colours were almost entirely masked. A half litre flask filled with a solution so dilute, that ten minutes or more elapsed after acidifying before opalescence was first visible, gave very feeble yellow and orange; the rose and rose-purple, though decidedly weak, reminded me in tint of the colours seen towards the upper margin of the recent sky-glows; but when the full purple, violet, and blue were reached, the colours were very strong and well marked. A gas or candle-flame, viewed through the solution, which was violet by transmitted daylight, appeared emerald green. After passing the blue stage, the colours through green and yellow were much weaker, until, as before mentioned, a neutral tint was reached. Beyond this, with such a dilution, nothing further could be satisfactorily observed; but by taking a much more capacious flask, and using a solution only one-half or one-third the former strength, faint orange and pink were again observed *after* passing the neutral point. And with these more dilute solutions, very strongly marked secondary effects were noticed after once passing the "blue stage." A distorted image of a window was formed in the flask, and while the bright portions appeared greenish, those parts where the dark bars of the framework fell, appeared of a fine crimson colour; after the neutral point had been passed, and the bright parts appeared pink, the dark portion of the image appeared a brilliant emerald green. In either of these stages a part of the solution transformed to a tall, but narrow glass cylinder, had not sufficient depth to show any perceptible colour when viewed by transmitted light, but placed on a dark background below a window, showed a crimson or green glow respectively when viewed at a certain angle, and a complementary glow when seen at a different angle (by raising or lowering the level of the eye, the cylinder remaining stationary).

With the solution in any given stage of development, the effect of increasing the depth of the column through which the light passed was to increase the saturation of the colour to a large extent, and to alter its tint (apparently in the direction of the less refrangible end of the spectrum) to a much smaller degree. That the colour observed at any given stage was owing mainly to the size of the individual particles rather than to their greater or less proximity, was shown by the fact that, on pouring away half or two-thirds of the contents of the vessel, and filling with water, the colour, although much thinner, was nearly of the same tint.

I am not able to give the proportion by weight of the salt in the solutions experimented with; but I think about one gramme or less to the litre will be found to give good results. One or two trials, however, would soon indicate the appropriate strength.

The character of the colours and the whole nature of the phenomena led me to infer that they were in all probability caused by the *interference* of light; but as I could not see my way to a *rationale* of the mode of action, I deferred publication in the hope that by further investigation their exact nature and true cause might be more clearly worked out. The description in last week's Nature (p. 439) of Prof. Kiessling's ingenious

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